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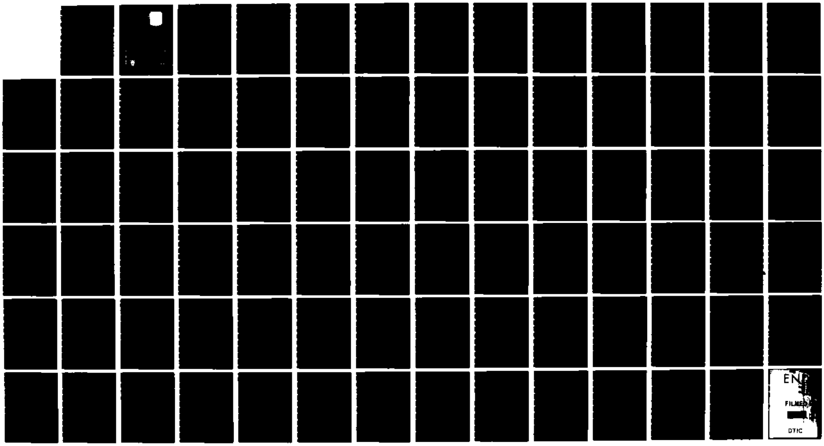

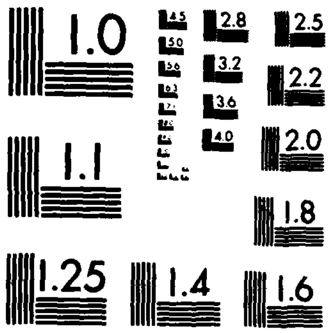

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STUDY PROJECT

ARTIFICIAL INTELLIGENCE APPLIED TO THE COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE OF THE U.S. CENTRAL COMMAND

BY

JAMES N. ENYART
NATIONAL SECURITY AGENCY

6 JUNE 1983

US ARMY WAR COLLEGE, CARLISLE BARRACKS, PA 17013

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A137 205	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Artificial Intelligence Applied to the Command, Control, Communications, and Intelligence of the U. S. Central Command		5. TYPE OF REPORT & PERIOD COVERED Study Project
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James N. Enyart		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army War College Carlisle Barracks, PA 17013		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Same		12. REPORT DATE 6 June 1983
		13. NUMBER OF PAGES 70
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

This document has been approved for public release and sale; its distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Not necessary to fill in.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study offers commanders and managers an operational perspective of the steadily evolving technology of artificial intelligence (AI). This primer discusses AI within the context of its probable future application to command, control, communications, and intelligence (C3I). The technological advances in command, control, and intelligence collection and communications capabilities the concurrent inundation of data into command facilities, and the limited number of experienced personnel available to analyze the material are the

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catalysts to investigate the current as well as future assistance that may be available through AI systems. And as it will be pointed out, the human contribution to this environment is key to the success of AI systems.

In order for the reader to better understand the differences between current conventional computer services and those that capitalize on AI techniques, a little background as well as some fundamental building blocks of this newly emerging art are introduced.

Because the scope of C3I is so large and the research and applications of AI continue to expand, the study focuses on the specific subfields of artificial intelligence that the Intelligence and Operations Centers will employ as they manage C3I activities. A hypothetical scenario reflecting a United States and Soviet Union military confrontation in Iran is employed to demonstrate how an artificial intelligence-based automated capability would aid the decision makers of the U. S. Central Command in the prosecution of their combat command and control responsibilities.

Following the scenario will be a report on the current state of the art and then what the future portends with respect to fifth generation computers and their integral AI components. The study concludes with observations recognizing that AI is currently the only viable solution to the unwieldly information explosion to decision-making continuum. Even though all the hardware and software tools to resolve this problem are coming to the fore, there still remains much to be accomplished in the future. To capitalize on the potential of artificial intelligence, the services must develop a long range training program for AI skills which would include the staffing of selected C3I center positions with personnel possessing both computer and telecommunications knowledge.

USAWC MILITARY STUDIES PROGRAM

ARTIFICIAL INTELLIGENCE APPLIED TO THE COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE OF THE U.S. CENTRAL COMMAND

INDIVIDUAL STUDY PROJECT

by

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6 June 1983

ABSTRACT

AUTHOR: James N. Enyart, National Security Agency

TITLE: Artificial Intelligence Applied to the Command, Control, Communications and Intelligence of the U.S. Central Command

FORMAT: Individual Study Project

DATE: 6 June 1983 **Pages:** 79 **CLASSIFICATION:** Unclassified

This study offers commanders and managers an operational perspective of the steadily evolving technology of artificial intelligence (AI). This primer discusses AI within the context of its probable future application to command, control, communications, and intelligence (C3I). The technological advances in command, control, and intelligence collection and communications capabilities, the concurrent inundation of data into command facilities, and the limited number of experienced personnel available to analyze the material are the catalysts to investigate the current as well as future assistance that may be available through AI systems. And as it will be pointed out, the human contribution to this environment is key to the success of AI systems.

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Following the scenario will be a report on the current state of the art and then what the future portends with respect to fifth generation computers and their integral AI components. The study concludes with observations recognizing that AI is currently the only viable solution to the unwieldly information explosion to decision-making continuum. Even though all the hardware and software tools to resolve this problem are coming to the fore, there still remains much to be accomplished in the future. To capitalize on the potential of artificial intelligence, the services must develop a long range training program for AI skills which would include the staffing of selected C3I center positions with personnel possessing both computer and telecommunications knowledge.

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CHAPTER I

INTRODUCTION

Background/Statement of Problem

Essential principles within the doctrine for fighting on the future battlefield are agility, depth, initiative, and syncronization. The implementation of these cornerstones places a premium on a unified force's ability to successfully employ its command and control systems. Sensing the adversary's posture and probable intent, making decisions based on that knowledge, and executing the selected course of action through the timely dissemination of information, all aspects of a command and control system, are essential for the accomplishment of the mission. Accordingly, each combat unit headquarter's requirement to reduce the ambiguities and incompleteness of the situation as much as possible has resulted in the advent of sophisticated sensors capable of collecting and forwarding volumes of intelligence.

Thus, at the confluence of modern technology, its benefits and burdens, and the soldier's cognitive ability to prosecute the future battle is the contemporary military command center. One of the benefits of the remarkable technological achievements during the last fifteen years to multiply the combat power of U.S. forces has been the implementation of sensors. The consequential burden has been that the suite of hardware and software that serve a Command's staff and analysts are barely, and in some instances, not at all adequate to accept and process all the available information. Necessarily then, the analysts

who must themselves peruse and comprehend the data cannot maintain the required pace to sort the essential from the nonessential. Another ramification of the technologically enhanced battlefield is that the range of the commander's decision options increases, and conventional software methods can no longer respond in the manner required.[1] Unless there is an advancement in analyst support and decision-making aids commensurate with the sensor enhancements that are occurring, the capacity and capabilities of the command center to grasp and apply the pertinent knowledge will deteriorate.

The irony of the technological revolution is that even more automated services are required to accommodate the impact of the previous advancements. An integral component of automated services is the staff of highly trained specialists who must be available to maintain and enhance the system as well as instruct the operators. Consequently, in addition to having staff and analysts to fight the war, there is now the real need for more combat service support to keep the computers functioning. To address this problem, the unit headquarters must integrate an evolving technology wherein the centers' command and control performance is no longer constrained by current computer capabilities and ancillary personnel, but by the intellectual and communication skills of the commander, his staff and analysts.

This new technology will replace the current systems which are delimited to processing only the data present and responding to only those situations embedded in the program design. The new role of computers as decision aids means the system must supplement their current data-dependent functions by emulating

the human reasoning process. This entails cognitively acquiring and selecting appropriate knowledge to solve a problem and then communicating the results.[2]

This well-known command center data volume dilemma is reinforced each time a US military exercise takes place. As an initial reaction, The Combat Capabilities Analysis Group (CCAG) of the U.S. Central Command, cognizant of the sensor overload phenomenon while concurrently aware that an artificial intelligence capability evolution is occurring, requested a primer that provides an overview of what artificial intelligence techniques could be successfully applied to minimize the impact of the arriving volumes of data, and subsequently aid the commander's decision making process. The Strategic Studies Institute of the U.S. Army War College (USAWC) also has a similiar interest in a description of AI and the services it may provide in the future throughout the data collection, fusion, correlation process, and subsequently, the analysis, projection, and assessment and presentation of options to the commander for his decision.

For that purpose, the specific questions the CCAG has posed include:

(1) What combinations of AI and US military C3I exist or are possible now?

(2) What are the projections and trends for AI systems in the near-, mid-, and long terms?

(3) What are the approximate costs/benefits of AI/C3I?

Due to the extensive analysis that would be required to

project the research and development costs of an AI system, this question cannot be answered at this time.

(4) With respect to weight, size, and harsh environmental impact on the deployability, maintainability, and sustainability of the system, to what combat unit level may an AI system realistically support?

(5) Can the software facilitate a user-friendly environment?

The thrust of the study therefore is to address these concerns, relate them to the responsibilities of the Central Command and present the research results as essentially a distillation for the concerned commander/manager who requires a cursory knowledge of the subject, but does not have the time for a thorough perusal of the rapidly increasing number of articles, books, and programming manuals on AI.

Investigative Procedures

Efforts during research for the project included meeting under the sponsorship of the USAWC Strategic Studies Institute (SSI) and the auspices of the Combat Capabilities Analysis Group (CCAG) of the Central Command with representatives of the J2, J3, and CCAG, to include the Battlefield Management Cell, to learn of deployed command center operations and refine the study's requirements. Attendance at a one week symposium on Command, Control, Communications, and Intelligence presented by the Armed Forced Communications Electronics Association and the perusal of many research and professional journal articles on C3I, the Central Region, and artificial intelligence were very

informative. Additionally, books on both the development of AI and the associated programming languages were referenced.

To supplement the reading and to better understand the scope of AI, the author met with well-versed individuals from the services, to include the Fort Leavenworth Army Model Improvement Program Management Office of the Army Combined Arms Center, the National Security Agency, the U.S. Central Command, and private sector organizations such as MITRE and M/A-COM LINKABIT. A great deal was also learned from the knowledgeable and helpful USAWC faculty and SSI staff as well as the curriculum which provided many insights to the Central Region, Command and Control, and Intelligence in the 80's through both the Common Overview and the Advanced Courses.

Organization of the Paper

As preparation for the central discourse on the art of applying AI techniques to C3I, the subject of C3I will be cursorily examined with respect to its definition, components, and sample problem areas where the timely exploitation of C3I data is a major concern. Artificial intelligence is actually an umbrella-label covering many disciplines. Thus, after a definition of AI, descriptions of a selection of its subfields will follow to set the stage for an examination of the AI disciplines that best address the volume problems inherent with C3I. With the lessons of the relevant components of AI as background, Chapter VI will apply the techniques to a hypothetical scenario engaging U.S. and Soviet forces in Iran. Chapter VII will review the status of AI as it exists today and

then what the technological revolution portends for artificial intelligence with respect to software, and militarized hardware in the mid- and long terms. The author's recommendations and observations will then conclude the study.

CHAPTER I

FOOTNOTES

1. David A. Brown and Harvey S. Goodman, "Artificial Intelligence Applied To C3I," ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION PROFESSIONAL PAPERS SESSIONS, p. 2.

2. *Ibid.*

CHAPTER II

THE HUMAN INFLUENCE ON C3I

A Review of Command and Control

There has been a veritable explosion of the literature on command, control, communications, and intelligence. Accordingly, this chapter will refrain from recapitulating a subset of the available technical literature, and will attempt to reflect on a few important human-engineering issues borne of the C3I revolution and their central role in the evolution of AI.

Included in Lieutenant General John H. Cushman's, (U.S. Army Ret.) assessments on command and control of theater forces are many insights, based on his previous command responsibilities, on the role of the networks or "webs" of C3I and its human dimension. Central to his observations on the operational transition from a man and paper intensive command center of an earlier era to a contemporary headquarters that relies extensively on technology is the human element. Incidently, General Cushman considers command and control to encompass "communications" and "intelligence" and hence the use of "C2" instead of "C3I" whenever his work is referenced in this chapter.

As a reminder, the Joint Chiefs of Staff define command and control as "The facilities, equipment, communications, procedures, and personnel essential to a commander for planning, directing, and controlling operations assigned forces pursuant to the missions assigned."[1] The technological advances during the past decade to modernize the U.S. command and control capability have at once (1) provided continually evolving quality C2 systems

to effectively employ U.S. forces, and (2) coalesced the computers, communications, personnel, and procedures to the point where they are operational extensions of each other. The consequence in a theater, for example, is that there exists a network or "web" of unique command and control systems extending throughout the force. Each C2 system within the web has been specifically tailored to the situation for which the unit commander has responsibility.

<u>The Human Dimension</u>

Thus, as the commander turns to technology to improve the readiness of his C2 system, he encounters the human element, the dimension of command and control upon which his mission accomplishment depends. This human component offers intelligence, resourcefulness, innovation, motivation and dedication to the mission as well as loyalty to the command. As noted earlier, the symbiosis of man and machine is a characteristic that distinguishes command and control systems from other military resources.[2]

Consequently, command and control of air/land battle forces can be described as the distributed, repetitive performance throughout the force of an essentially simple cycle in which countless individuals and command entities with the aid of their systems will:

a. Sense the situation. A sensor reports one thing. Radio traffic reflects another. In the "fusion center" or at the command post, an algorithm on a tiny chip correlates these two data elements along with

previously received others. Now an interpretation is possible. Before computers, this correlation would have been lost.

b. Consider and decide what to do about it. Today these are matters for people alone, not for computers. Some distant day, when computer scientists and "artificial intelligence" experts understand far better than they now do how commanders in battle arrive at their judgements, it may be possible to assess tactical situations and perhaps the system can be trusted to make "decisions." But for today it is enough to ask the computer simply to assist in "sensing" and "understanding."

c. Execute the decision (or issue instructions for its execution). Modern computer-based telecommunications allows the will of the commander to be made known in broadcast form to all who need to know it, free from enemy jamming, quickly, in the cogent language of battle -- and allows for the commander to know that his battle scheme has been received and is understood by all.

d. Continue to sense the situation, thereby starting the cycle again.

Throughout this cycle, and imbedded in each part, is human thought. The dramatic change today is the ability of technology to reinforce the individual as he (or she) participates in the cycle.[3]

Noted in the preceding chapters have been a few of the key C3I concerns of the modern battlefield: (1) volumes of sensor-forwarded data signaling the perceived status of both friend and

foe; (2) an expanding network of command and control capabilities currently deficient in the required capacity to react to the information in a timely manner; (3) the promising technological revolution whose field implementation (10-15 years) has not been timely; and (4) the essential analyst, who at once, both depends on his web of systems, but yet is unsure that he is or will be the master of it. With these human-based operational realities as motivation, the next three chapters will offer an overview of artificial intelligence as preparation for understanding how this evolving art may minimize the adverse impact of the four circumstances described above.

CHAPTER II

FOOTNOTES

1. Joint Chiefs of Staff, _U.S. Department of Defense Dictionary of Military and Associated Terms, JCS Pub 1._

2. John H. Cushman, LTG (Ret.), _Command and Control of Theater Forces -- Adequacy, Options and Implications (Draft)_, pp. 2-31,32.

3. _Ibid._, pp. 2-53,54.

CHAPTER III

ARTIFICIAL INTELLIGENCE

Definition

Artificial Intelligence (AI) is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior -- understanding language, learning, reasoning, solving problems, and other human capabilities.[1] AI is the study of the relation between computation and cognition. Thus, research in AI involves producing software that attempts to achieve some kind of intelligent behavior.[2]

As with most scientific disciplines, there are several distinct areas of research, each with its own specific interests, research techniques, and terminology. In AI, these specializations include research on language understanding, robotics and vision, problem solving, and expertise systems. Similar to the different subfields of AI, the different behaviors discussed are not all independent. Separating them is just a convenient way of indicating what current AI programs can do and what they cannot do. Most AI research projects are concerned with many, if not all, of these aspects of intelligence.[3] The disciplines of AI include:

Problem Solving

The first achievements in AI were programs that could solve puzzles and play games similar to chess. Techniques such as looking ahead several moves and dividing difficult problems into

easier subproblems evolved into the fundamental AI techniques of "search" and "problem reduction". The open questions in this area involve capabilities that human players have but cannot articulate, such as the chess master's ability to see the board configuration in terms of meaningful patterns. Another question involves the original conceptualization of a problem, called in AI the choice of problem represention. Humans often solve a problem by finding, through free-ranging thought patterns, a way of thinking about it that makes the solution easy. AI programs, so far, must be told specifically how to think about problems they solve (i.e., the space or range of possibilities in which to search for the solution).[4]

Learning

Certainly one of the most significant aspects of human intelligence is the ability to learn. This is a good example of cognitive behavior that is so poorly understood that very little progress has been made in achieving it through AI systems. There have been several interesting attempts, including programs that learn from examples, from their own performance, and from being told. But in general, learning is not noticeable in AI systems.[5]

Robotics and Vision

Another part of AI research that is receiving increasing attention involves programs that manipulate robot devices. Although more complex systems have been built, the thousands of robots that are being used today in industrial applications are simple devices that have been programmed to perform some

repetitive task. Most industrial robots are "blind", but some see through a TV camera that transmits an array of information back to the computer. Processing visual information is another very active, and very difficult, area of AI research. Programs have been developed that can recognize objects and shadows in visual scenes, and even identify small changes from one picture to the next, for example, for aerial reconnaissance.[6]

Expertise

Recently the area of Expert Systems, or "Knowledge Based Systems (KBS)" has emerged as a road to successful and useful applications of AI techniques. Typically, the user interacts with an expert system in a "consultation dialogue", just as he would interact with a human who had some type of expertise -- explaining his problem, performing suggested tests, and asking questions about proposed solutions. Expertise, as one would suspect, consists of knowledge about a situation as it exists, understanding of problems, and skill at solving such problems. Thus the field of expert systems investigates methods and techniques for constructing man-machine systems by applying specific real-world expertise.[7]

Although there exists a spectrum of expert/knowledge engineering systems which vary widely in structure and behavior, all rely on one important methodology, called the transfer of expertise. Early in AI history, researchers agreed that high performance on difficult problems would require large amounts of real-world knowledge, the knowledge that an individual has learned from his experiences. The idea of expert-systems

research (or "knowledge engineering") was to find ways of transferring the necessary kinds and quantities of knowledge from human experts to AI systems. An example of a successful AI system is one which "knows" how to play chess. A chess-playing system has the intelligence to project many moves ahead and ascertain the consequences of each countermove. The system would then select its next best move.

Natural Language

Language (i.e., English) understanding was also investigated by early AI researchers and has consistently attracted interest. The principal themes of current language-understanding research are the importance of vast amounts of general, commonsense "world knowledge" and the role of "expectations" based on the subject matter and the conversational situation. The implementation of practical language programs is represented by useful "front ends" to a variety of software systems. These programs accept input from a user in some restricted form. They cannot, however, handle some of the nuances of English grammar and are thus only useful for interpreting sentences generated from a relatively limited set of words. As an example of the consequences of these language constraints, an analyst would submit a list of parameters, not sentences, to query his order-of-battle data base.[8]

Programming Languages

In addition to work directly aimed at achieving intelligence, the development of programming languages has always

been an important aspect of AI research. Specialized programming languages and systems, with features designed to facilitate deduction and cognitive modeling have often been rich sources of new ideas. Most recently, several knowledge-representation languages -- computer languages for encoding knowledge and reasoning methods as data structures and procedures -- have been developed in the last five years to explore a variety of ideas about how to build reasoning programs.[9]

Since the attention of this study is primarily on the AI support to be provided to the Joint Intelligence and Operations Centers, and by operational extension, the Battle Management Cell, and from the above descriptions of some of the different subfields, it may be gleaned that the Expertise and Language, both Natural and Programming, disciplines are most germane to the study's interests. Thus a survey of the most relevant basic building blocks of each of these components will be presented.

CHAPTER III

FOOTNOTES

1. Arron Barr and Edward A. Feigenbaum, eds., _The Handbook of Artificial Intelligence, Vol. I_, p.3.

2. Arron Barr and Edward A. Feigenbaum, eds., _The Handbook of Artificial Intelligence, Vol. II_, p.3.

3. Arron Barr and Edward A. Feigenbaum, eds., _The Handbook of Artificial Intelligence, Vol. I_, p.7.

4. _Ibid._

5. _Ibid._, p.8.

6. _Ibid._

7. Frederick Hayes-Roth, "Artificial Intelligence and Expert Systems", _First U.S. Army Conference on Knowledge-Based Systems for C3I_, p. 102.

8. Arron Barr and Edward A. Feigenbaum, eds., _The Handbook of Artificial Intelligence, Vol. I_, p.8.

9. _Ibid._, p.8.

CHAPTER IV

EXPERT/KNOWLEDGE-BASED SYSTEMS

Description

An Expert or Knowledge-Based System is composed of three major components: a **situation** database; a **knowledge** database; and a **control system.** Figure 1 illustrates the components and their relationships.[1] Chapter VI will portray these components in an operational context. The **situation** data base contains a representation of the current situation including all relevant background information and the goal.[2] This database can consist of different data structures including arrays, lists, sets of language expressions, and **frames.**[3] Frames are one of the more recently developed situation-representation schemes. Essentially, a frame is a structure for neatly associating an entity, such as an airplane, with its attributes or properties (i.e. range, speed, maximum altitude and mission). For example, in an information retrieval situation, the database may consist of (1) sets of facts such as Ground, Air, and Elint Orders of Battle and (2) continually arriving intelligence-bearing messages. The goal of the retrieval could be the locations of a designated type of radars.

The **knowledge** database is the component of the system which contains the "expertise." Included in "expertise" are assertions, cause-effect relationships, heuristics, and plans of action or analytic procedures.[4] A formal way of describing cause-effect relationships in the knowledge base is by identifying them as **productions.** They are of the form, "if this condition occurs, **then** complete this action." Illustrations of

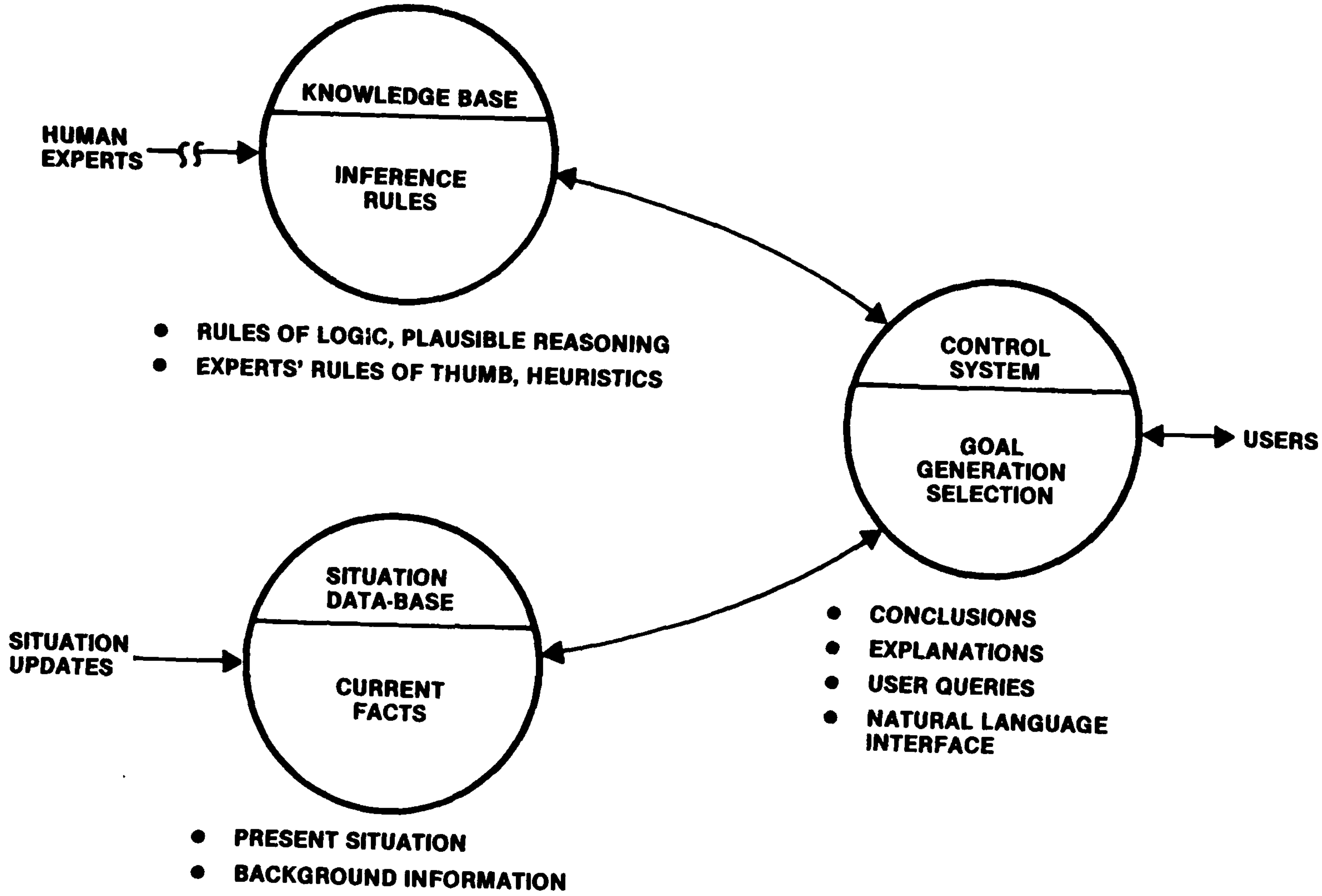


FIGURE 1. KNOWLEDGE BASED SYSTEM (KBS) COMPONENTS

"assertions" and "if-then" statements are, respectively:

(a) A MIG-23 FLOGGER B/G has a max speed of 1350 knots and a max radius of 1200 kilometers

(b) **IF** FLOGGER is west of East German border

THEN send alert message to SACEUR

The utility of the formalism comes from the fact the conditions in which each rule is applicable are made explicit and, in theory at least, the interactions between rules are minimized (one rule is not linked to another).[5] Because they facilitate human understanding and modification of systems with large sets of rules, production rule systems are condusive to employment in a dynamic environment such as a command post.

The **control system** decides how best to apply the knowledge base of productions to the situation database. The selection of a control strategy affects the contents and organization of the data bases. In general, the object of an expert system is to achieve a goal by applying an appropriate sequence of productions to an initial situation. The sequence of moves in Chess is an example of this concept. In essence, the control system is the applications software that must be written and tailored to solve the designated problem, whether its fusing and correlating intelligence or aiding the commander's assessment of a course of action.

The application of productions to those structures in the data base that comprise the situation -- to produce a "modified situation" -- is often called **reasoning forward.** The objective is to bring the situation forward from its initial configuration

to one satisfying a goal condition. The goal in chess, of course, is to "checkmate" your opponent. All the intervening moves that bring the game from its initial setup to its conclusion are the modified situations.

To begin at an initial state and progress through successive steps or situations until the goal is attained is termed the **search**. The critical problem of search is the amount of computer time and memory necessary to reach the goal. Little theory exists about how to best represent the interim situations between the initial one and the last in order to efficiently traverse the continuum. A second aspect concerns search efficiency within a given search space.

Heuristic Knowledge

Of special interest are those search methods that use **heuristic knowledge** about the situation database to organize the search. Although the term **heuristic** has long been a key word in AI, its meaning has varied. For purposes of this study, a **heuristic** is "a rule of thumb, strategy, trick, simplification, or any other kind of device which drastically limits search for solutions in large problem spaces. Heuristics do not guarantee optimal solutions; in fact, they do not guarantee any solution at all; all that can be said for a useful heuristic is that it offers solutions which are good enough most of the time".[6] In some types of problems, these heuristic search techniques can prevent a combinatorial explosion of possible solutions. As a trivial case-in-point, when attempting to specifically identify an airplane located over the North Atlantic and on course to

Cuba, there is only the need to search the long-range air order-of-battle (AOB), for obviously only that type of aircraft has the range. Intuitively eliminated from the search are the "fighter" AOBs. Heuristic search is one of the key contributions of knowledge-based system to efficient problem solving. Heuristics has been emphasized at this point, for it relates to the dynamic operable human dimension of the system. Heuristics is the expression of the experience and intuition the analyst applies to his craft. When the criteria for an effective C3I decision loop is that it must turn inside the enemy's decision process, the intellectual "short-cuts" to provide the commander with the right assessments are invaluable.

Whereas in the typical automated systems currently in use, the computer provides for a seqential execution of software instructions, an expert system operates in "cycles." In each cycle, the productions are examined in the manner specified by the control strategy to see which ones match the parameters or conditions presented by the arriving-message's content. If multiple productions are found appropriate, one is selected from among them. Finally the selected "if condition -- then action" rule is executed. These three phases of each cycle are described as **matching**, **conflict resolution**, and **action**.[7]

Another significant difference between existing computer systems and those that possess an artificial intelligence capability is that the former are digital machines; that is, they are primarily number processors. It is quite true that they may scan text for a pattern match and subsequently initiate an appropriate follow-on activity, but essentially, this is an

under-developed skill. Expert systems, however, are "symbolic" processors. As related earlier, the knowledge database contains the productions (or rules), and they are prescribed in a grammar as close to normal English as possible. These words and phrases, representing entities, declarations about these entities, and condition-action statements are the "symbols" that are cyclically and continuously processed.

But someone, that is, an analyst, must provide his expert system with the "symbolics". The system must be able to reformulate a problem described by a natural language into an internal representation convenient for processing with its expert rules.[8] Accordingly, the second of the major artificial intelligence disciplines of interest to this study, Natural Language, will be addressed in the next chapter.

To conclude this overview of knowledge-based systems, a summary of the advantages and disadvantages follows.

Advantages of the Expert System Approach

1. The knowledge base consists of symbolic knowledge rather than just numerical information.
2. The "program" and what the system knows are completely separate. In other words, the rules are not imbedded in the software.
3. Use of each rule is independent of what happens before or after, not a sequential list, not order dependent. (However, the order selected can affect time and efficiency so that good selection strategy is helpful.)
4. Because of (2) and (3), the system can be built

incrementally. Both adding and deleting rules from the knowledge base is easy. More rules make the system smarter. System performance is primarily a function of the size and quality of its knowledge base.

5. The system lends itself to parallel architectures. Its rules can be invoked in parallel.

<u>Disadvantages of the Expert System Approach</u>

1. An expert system can be inefficient as it processes. Because the program and its databases are separate and the knowledge base productions are encoded within a rigid structure, there is a resultant high overhead during problem solving. For example, since production systems perform every action by means of the match-action cycle, it is difficult to make them efficiently responsive to predetermined sequences of situations or to take larger steps in reasoning when the situation demands it. In other words, it is hard to either execute short-cuts through the knowledge database or invoke a combination of sets of productions to resolve a problem.

2. Because of the expert system formalism, it can be hard to follow the control strategy during problem solving. The sequence that the match-action cycles are executed in are less apparent than they would be if they were expressed in a programming language. Two factors that contribute to this problem, are the isolation of the productions (they are not linked to each other) and the

uniform size of productions (there is nothing like a subroutine hierarchy in which one production can be composed of several subproductions). The existence of functions and subroutines would help to make the flow of control easier to follow.[9] But that would call for an association between productions, an undesireable relationship in knowledge bases.

CHAPTER IV

FOOTNOTES

1. David A. Brown and Harvey S. Goodman, "Artificial Intelligence Applied to C3I," ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION (AFCEA) PROFESSIONAL PAPERS SESSIONS, p.4.

2. Ibid., p.3.

3. Arron Barr and Edward A. Feigenbaum, ed., The Handbook of Artificial Intelligence Vol. I., p. 22.

4. Brown and Goodman, p. 3.

5. Barr and Feigenbaum, Vol. I, p. 157.

6. Ibid., pp. 21-31.

7. Ibid., p. 192.

8. D.A. Waterman and Frederick Hayes-Roth, An Investigation of Tools for Building Expert Systems, p. 1.

9. Barr and Feigenbaum, Vol. I, pp. 193-194.

CHAPTER V

LANGUAGES

Natural Languages

As stated earlier, one of the key advantages of an expert system is the ability of the command center analyst to dvnamically manage the knowledge base of rules in response to the changing environment. In other words, the match-action productions can be readily updated to accommodate the decision-makers changing strategy. To accomplish this, however, an analyst requires a knowledge of the language that the computer system understands. In practice, the language that the computer "knows" about is not readily adopted by the inexperienced user. A lot of resources, personnel, money, and time, are engaged right now in attacking this man-computer interface language dilemma. The Joint Interoperability of Tactical Command and Control Systems (JINTACCS) efforts to standardize U.S. and NATO message text formats are in response to the automated inability to scan and understand the "who, what, where, and when" of a target when communicated in everyday jargon. JINTACCS is requiring that a man/machine readable, but highly structured, format be employed for the communication and automated processing and storage of the myriad types of tactical messages.

To overcome this shortfall, a significant artificial intelligence effort is being directed at the understanding of the way individuals communicate. English, French, and German are examples of natural languages. Data base management procedures and languages, on the other hand, seem awkward to humans. These "artificial" languages or grammars are designed so that sentences

have a rigid format, or **syntax**, making it easier for computers to analyze commands and convert them into the format that the computer understands. Besides being structurally simpler than natural languages, database languages can express easily only those concepts that specifically are tailored for a function. In addition, because words or phrases can possess more than one interpretation, the different meanings that can be expressed in a language are referred to as the **semantics** of the language.[1]

Thus far, programs have been written that are quite successful at processing somewhat constrained input. The user is limited in the structural variation of his sentences (syntax constrained by an artificial language). For an analyst to query the activities of a Tabriz, Iran airfield between 0900 and 1200, instead of entering "What is the status of Tabriz airfield between 0900 and 1200?", his parameters may look like:

```
Status
BT0900      (Begin time)
ET1200      (End time)
Tabriz
Airfield.
```

Some of the natural language systems are adequate for building English "front ends" (i.e., the program that handles the analyst's submissions) for a variety of data processing tasks. But the fluent use of language typical of humans is still elusive, and understanding natural language is an active area of research in artificial intelligence.[2]

As AI researchers studied natural language, they began to view human language as a complex cognitive ability involving knowledge of different kinds: the structure of sentences, the

meaning of words, a model of the listener, the rules of conversation, and an extensive, shared body of general information about the world. Consequently, the general AI approach has been to model human language as a Knowledge-Based System for processing communications. Because the product of natural language processing ends up in the knowledge base, the development of this discipline has been closely associated with the AI work on data base structures and its internal representation of knowledge.[3]

Parsing is the "delinearization" of linguistic input, that is, the use of grammatical rules and other sources of knowledge to determine the functions of the words in a sentence and subsequently create a data structure. This structure depicts some of the relations between words in a sentence ("this adjective modifies that noun, which is the object of a prepositional phrase...") and can be used to get at the "meaning" of the sentence. All natural-language-processing computer systems contain a parsing component of some type. Those of the early natural language programs were based on keywords expected in the input or were constrained to quite limited phrase structures. The practical application of grammars to the full range of natural language has proved difficult.[4]

Programming Languages

To conclude the overview of the functional components of an expert system, a brief look at the tools available for the programmers of artificial intelligence systems is required, for the system performance is no better than the software that runs

it. Besides the computers themselves, the most important tools in AI are the programming languages in which these programs (that is, control strategies) are conceived and implemented. A programming language provides a means of specifying the objects and procedures needed to solve certain classes of problems. Languages such as FORTRAN and COBOL were developed to make this specification easier by supplying higher level algebraic and business grammars, respectively. Contemporaneously with the development of these languages, researchers in AI were developing their own progamming languages with features designed to handle AI problems.

AI programming languages have had a central role in the history of artificial intelligence, serving two important functions. First, they allow convenient implementation and modification of programs that demonstrate and test AI ideas. Second, they provide vehicles of thought. As with other high-level languages, they allow the programmer to concentrate on higher level concepts. Frequently, new ideas in AI are accompanied by a new language in which it is natural to apply these ideas.[5]

The first and most fundamental idea in AI programming languages was the use of the computer to manipulate arbitrary symbols -- symbols that could stand for anything, not just numbers. To form associations of these symbols, list processing was introduced, which allowed programs conveniently to build data structures of unpredictable shape and size. When parsing a sentence, one cannot know ahead of time the form of the data structures that will represent the meaning of the sentence. The

unconstrained form of data structures is an important characteristic of AI programs.

The problem of unpredictable shape of data structures was solved by use of primitive data elements, **cells**, consisting of two fields, each of which could hold either a symbol or a **pointer** to another cell. This simple arrangement is called a **list structure.** For example, an array (or matrix), normally stored as a sequence of words in memory, can be thought of as a list of cells whose left halves each contain a symbol and whose right halves each contain a pointer to the next memory location.[6]

The concept of list processing was incorporated into LISP, the mainstay of AI programming languages. Since its invention in 1958, LISP has been the primary programming tool used by the vast majority of AI researchers. The reasons for this are in part historical. LISP was established early, several large systems have been developed to support programming in the language, and all students in AI laboratories learn LISP, so that it has become a shared language. However, the language continues to be the natural vehicle for AI research because there are features of LISP that are critically important in AI programming. For instance, recursive use of "if-then" expressions and representation of symbolic information externally by lists and internally by list structures are used.[7]

LISP is a good case in point in distinguishing AI computers from digital computers, as mentioned at the end of Chapter IV. Besides it use of list structures as its only data type, LISP probably differs most from other programming languages in its

style of describing computations. Instead of being described as a sequence of steps, LISP programs consist of functions defined in a rather mathematical format. Each function call is represented as a list whose first element is the name of the function and whose other elements are the arguments. As an example of the format, consider the procedure to calculate the "factorial" of a number. "Factorial" is the name of the function and each of the other symbols or combination of symbols (those that are enclosed in parentheses) are called the "arguments."

```
FACTORIAL (N):
     (COND (EQUAL N 1)    1)
     (    TRUE    (TIMES N (FACTORIAL (DIFFERENCE N 1)))))
```

Currently, all the systems that use LISP offer support for creating and modifying procedures for managing the hundreds of individual procedures that make up a LISP program, and for debugging those systems interactively. LISP lends itself to incremental program writing, an important feature of expert systems. It is also straight forward to accomplish test-and-evaluate modifications, another flexibility characteristic of expert systems.[8]

Although LISP and its enhanced-capability spin-off languages, MACLISP and INTERLISP, are the predominant AI software development tools, there are numerous others. For another example, with the PLANNER language, the programmer expresses his program in terms of a collection of statements, called theorems, about how to achieve goals given certain preconditions and about what to do should certain situations arise in the process.

A very recent addition to artificial intelligence

programming languages is ROSIE (Rule-Oriented System for Implementing Expertise). It is a programming environment developed at the Rand Corporation under contract from the Defense Advanced Research Projects Agency. ROSIE is a stylized version of English with a primary design objective of achieving program readability. The language allows the programmer to describe complex relationships simply and to manipulate them symbolically and deductively. It is a general-purpose language capable of handling normal data structures found in most high-level languages as well as a few used only in AI languages. Using ROSIE, a programmer can think concretely about the problem and translate ideas into a program using substantially the same vocabulary that arises in the English (non-computational) formulation of the model.[9]

The following comparisons may provide a better understanding of some the basic programming language elements.[10]

ENGLISH	LISP (and PLANNER)	ROSIE
Move force to Dezful within 6 days.	(THAND(THGOAL(DATE?)(AT DEZFUL' (FORCE)DATE?)) (LESSP(CURRENTDATE)DATE?' (6 DAYS)))	Go move force to Dezful within 6 days

Although not currently an artificial intelligence programming language, Ada will be briefly described as it will assume a vital role as automated military computer systems are fielded in the 1990's. Ada is the product of a lengthy effort by the Department of Defense to reduce the cost and increase the quality of military applications software. The intention is that all new software be written in Ada as early as 1990, with a phase-in period through the late 1980's.

Ada contains a unique combination of features, all of which occur in other computer languages or are well understood. It is a language which accommodates effective program development more easily than many of the tools in current use. Ada's structure and features are expected to simplify software maintenance, thereby reducing costs. Ada has English-like syntax and allows lengthy data names, which aids readability. Since Ada will be a standard, the need to train programmers in application-specific languages will be reduced. Software developers will be more easily transferred from project to project. Thus, Ada's appropriateness to military applications, its portability, and the expected widespread availability of reusable software components, are providing a great incentive for its use both on DoD applications and in the commercial world.[11]

From the above descriptions of programming languages, a potential conflict may have been noted. First, there are the expert systems whose efficiency depends on software that promotes cyclical rather than the sequential processing of conventional computers (page 23). Secondly, it has been mandated that the non-cyclical Ada will be the programming language for military systems of the future. To resolve this conflict, Ada, since it is in its formative stages will be enhanced to perform in AI systems. TRW, for one, is actively engaged in this effort.

Modern AI Programming Environments

Current programming in AI is done predominantly on DEC PDP-10s and PDP-20s in LISP, principally in MACLISP or INTERLISP. Other LISP dialects, for the DEC VAX machine and for several

other machines are in relatively sparse use, as are some other general-purpose languages like SAIL, POP-2 (used mostly in Great Britain), and PROLOG (used mostly in Europe). The recently introduced LISP machines promise to alter AI programming environments radically.[12]

Although the last two chapters may have appeared too abstract with respect to the description of an expert system and the associated languages, it is important to understand the complexities involved in designing and developing an expert system. After all, the control center analysts, consulting with their commanders, are the "experts" who must interact, maintain, and update the "knowledge" base. Their success communicating with the system depends on the facility with the user/natural language. Necessarily then, the viability of the system is a function of the analyst's and decision maker's familiarity with it. Similarly, the commander should desire individuals for key command and control staff positions who readily identify with the operational environment to accomplish the control-strategy software. This caliber of programmer will not magically appear, but will have to be educated in the environment that his AI software will serve.

CHAPTER V

FOOTNOTES

1. Arron Barr and Edward A. Feigenbaum, ed., The Handbook of Artificial Intelligence, Vol. I, p. 225.

2. Ibid.

3. Ibid., p. 227.

4. Ibid., p. 229.

5. Arron Barr and Edward A. Feigenbaum, ed., The Handbook of Artificial Intelligence, Vol. II, p. 3.

6. Ibid., pp. 3-4.

7. Ibid., p. 5.

8. Ibid., p. 8.

9. J. Fain, et al., The ROSIE Language Reference Manual, pp. iii,v.

10. Fredrick Hayes-Roth, "Artificial Intelligence and Expert Systems", First U.S. Army Conference on Knowledge-Based Systems for C3I, p.100.

11. Judith S. Kerner and Dr. Richard L. Uznanski, "The Ada Programming Language: Its Impact on Systems Developers," ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION (AFCEA) PROFESSIONAL PAPERS SESSIONS, pp.1-3.

12. Arron Barr and Edward A. Feigenbaum, ed., The Handbook of Artificial Intelligence, Vol. II, p. 14.

CHAPTER VI

AI APPLIED IN AN EXAMPLE SCENARIO

The intent of the previous chapters on AI and its subfields has been to prepare the reader to be somewhat conversant with expert systems, so that when AI is applied in the context of a scenario, an understanding of the involved mechanics occurs. Therefore, to examine in more depth the services that artificial intelligence could reasonably provide during hostilities, a U.S./USSR confrontation in Iran is presented. Throughout this scenario, the artificial intelligence system that supports the CENTCOMM Intelligence and Operations Centers will be referred to as TRIAX. The functional software and hardware components of the mobile TRIAX include (1) a communications handler to accept messages and sensor data and distribute tactical intelligence reports; (2) a processing (control strategy) capability providing analyst support services and situation and knowledge data base management; and (3) graphics capability that, at the user's discretion, displays terrain and weather as well as orders-of-battle.

In-garrison Planning and Preparation

Although the scenario develops an isolated event, a great deal of pre-deployment preparation had already occurred prior to the movement of the CENTCOMM Headquarters. A review of the pre-deployment phase is appropriate, for the readiness of TRIAX is an essential part of the Command's preparation. An integral task of any in-garrison operations would be the preparation of orders-of-

battle and general files to reflect the status of the potential adversary's forces and environment (i.e., weather and terrain). As previously noted, one of the emminent characteristics of a Knowledge-Based System is that the quality of a system's performance relates directly to the quantity of real-world knowledge it possesses. Static knowledge, that which is seldom changed, would occupy one portion of a TRIAX situation data base. As a representative illustration of two types of static information that can be represented by frames and what an analyst can enter are: (1) the entities included in a target order-of-battle, for example, an air field, its air defense system, radars, and/or command and control facilities and their nomenclature; and (2) the U.S. air mission that has been initially projected against the air field. Types of U.S. air frames and their attributes are also emulated in a frame data structure. The noteworthy point is that the air mission "information frame" is discretionarily coupled to the target by the J2/J3 analysts. This linkage process facilitates a dialogue between the planner and TRIAX as he projects and tests various combinations of types of aircraft and types of missions.

Another portion of the situation file would be reserved for the storage of multi-source intelligence messages about the adversaries. It is critical that these reports be formatted so that they will accommodate expeditious processing and possible follow-on distribution. This is expressly required when smaller expert systems are to accompany units at the battalion level and below. At these lower echelons, the size and weight of machine support is important, for mobility is essential. Unfortunately,

the smaller the system, the less processing and storage capacity it possesses. Consequently, a message should be prepared with a one- or two-line communications/information prologue. This transmission mechanism contains key communication and subject information in a compact, readily accessible JINTACCS-compatible form and facilitates the processing effectiveness required by the forward-deployed systems. Additionally, at the system design/development level, the prologue easily becomes the index into the message situation data base which immediately facilitates analyst interaction.

Concomitant with the timely updating and analyst-maintenance of the situation files are the on-going actions to formalize a knowledge database that emulates the commanders decision-making processes. This repository of "if-then" statements and natural language "assertions" interacts with the dynamic situation database. The knowledge rules represent the best heuristic projections and actions derived from strategy and doctrine that are militated by the situation data base. The following is an example, at the strategic level, of a rule that Intelligence Center Indications and Warnings analysts would enter into the production database:

IF the number of planes at Kirovabad is greater than 85% of capacity,

AND no radio communications for more than four hours,

AND weather is average between Kirovabad and Tabriz,

AND leave for soldiers has been cancelled,

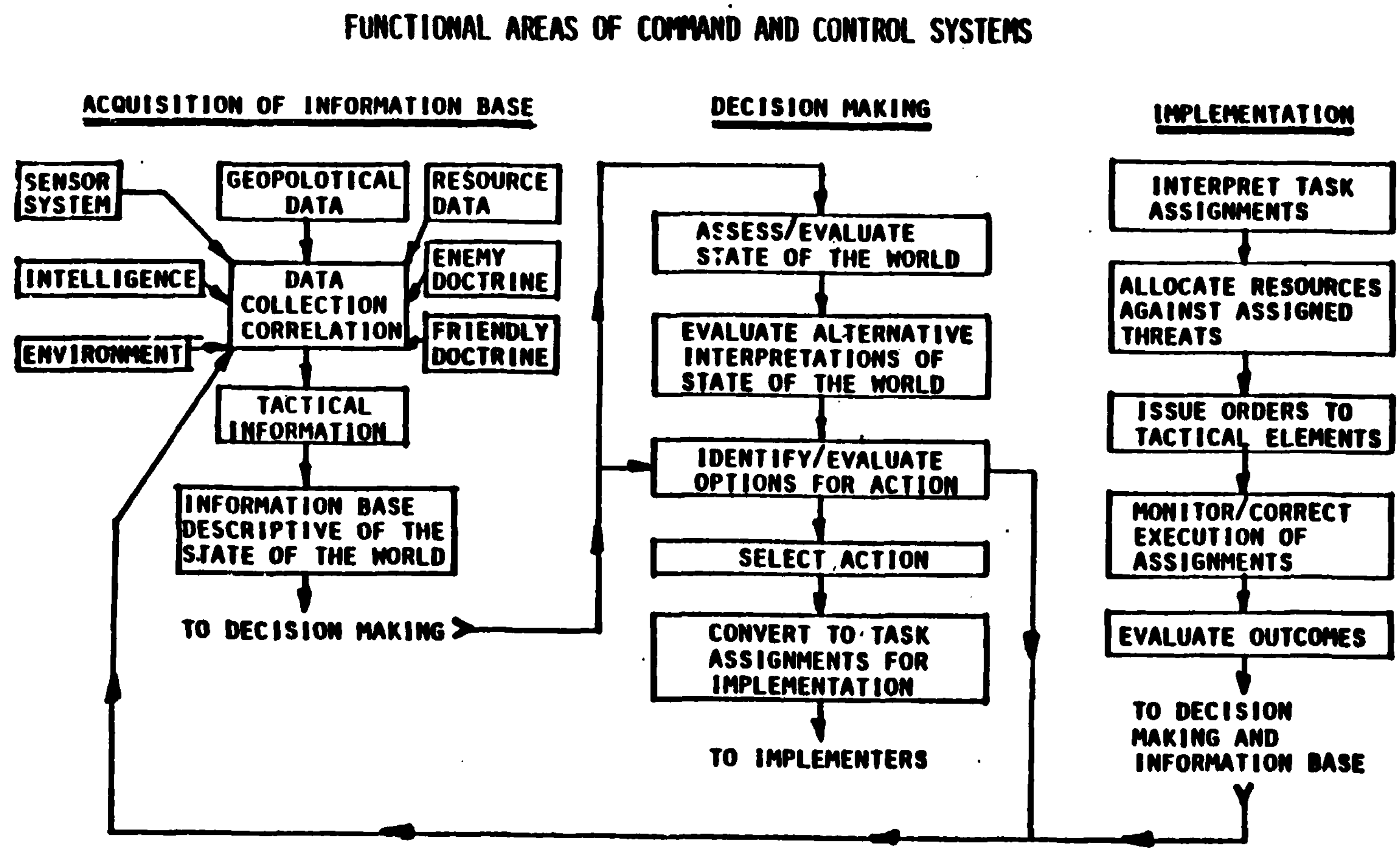

FUNCTIONAL AREAS OF COMMAND AND CONTROL SYSTEMS
ACQUISITION OF INFORMATION BASE
DECISION MAKING
IMPLEMENTATION
SENSOR SYSTEM
GEOPOLOTICAL DATA
RESOURCE DATA
INTELLIGENCE
DATA COLLECTION CORRELATION
ENEMY DOCTRINE
FRIENDLY DOCTRINE
ENVIRONMENT
TACTICAL INFORMATION
INFORMATION BASE DESCRIPTIVE OF THE STATE OF THE WORLD
TO DECISION MAKING
ASSESS/EVALUATE STATE OF THE WORLD
EVALUATE ALTERNATIVE INTERPRETATIONS OF STATE OF THE WORLD
IDENTIFY/EVALUATE OPTIONS FOR ACTION
SELECT ACTION
CONVERT TO TASK ASSIGNMENTS FOR IMPLEMENTATION
TO IMPLEMENTERS
INTERPRET TASK ASSIGNMENTS
ALLOCATE RESOURCES AGAINST ASSIGNED THREATS
ISSUE ORDERS TO TACTICAL ELEMENTS
MONITOR/CORRECT EXECUTION OF ASSIGNMENTS
EVALUATE OUTCOMES
TO DECISION MAKING AND INFORMATION BASE

FIGURE 2

THEN alert command of abnormal Soviet activity

AND send alert message to CINCPAC

The C3I center analyst's facility with TRIAX assumes some importance, for his success in interpreting the commander's strategy and concisely expressing the associated productions is to an extent dependent on the natural language processing sophistication of the system. If TRIAX's grammar precludes the words or expressions that convey the nuances of the commander's insights, the system may not adequately provide the required support.

The third component of TRIAX, the control strategy is also continually "fine-tuned" while the headquarters and system remain the U.S. The resident command center TRIAX software developer is very aware of the two potential operational constraints that must be considered -- storage capacity and processing priorities. Although TRIAX would (1) have a very large, but not infinite, message database and (2) never disregard any arriving traffic, the programmer/J2- or J3-analyst, consulting with his colleagues must prioritize the sensor information with respect to longevity of selected message retention. The control strategy must also consider the order of responses to potential hostile events occurring simultaneously. What are the CENTCOMM priorities for TRIAX processing and strategy if the Soviets move into northwestern Iran as well as south from Afghanistan into Pakistan? The software developer must encode the rules for determining the management of a Pakistan incursion in addition to an Iranian confrontation.

As the indications and warnings signal increasing Soviet preparations, the CENTCOMM Headquarters goes to an "alert" posture. The frequency of J2 and J3 interaction with TRIAX increases. In its support to the J2 and J3, TRIAX has different responsibilities. As summarized in Figure 2, the functions of the Intelligence Center include data collection and correlation as well as management of the acquistion of data from all available sources.[1] To support the Intelligence Center analysts, TRIAX knowledge base productions extract order-of-battle information from the intelligence traffic and trigger the automatic update of the associated files. "Templates", a combination of frames, representing the doctrinal posture of the echelons of the Soviet Frontal Armies are also filled in as the relevant information becomes available. An expert system excells in support of this environment, for its productions are accessing discrete information (who, what, where, and when) and matching it against the commander's criteria for signaling an accelerated awareness.

The function of TRIAX in service of the Operations Center is related to, but different from its J2 support. In this arena, TRIAX is asked to aid in the selection, projection, and evaluation of possible courses of action. Its success in accomplishing this function is related to the completeness of the "if-then" productions. Fortunately, an expert system's knowledge base can be updated to reflect any previously unaccounted for contingency. The productions that respond to the planning functions of the J3 are characterized by the Kirovabad example on page 39. TRIAX continually cycles through the situation data

base to determine if the conditions of the productions are satisfied. Once all the conditions are met, TRIAX initiates the associated action. If the criteria of two or more rules are accommodated; for example, sensors indicate that both a motorized rifle division is rapidly advancing and a squadron of attack planes are quickly approaching, the control strategy, encoded to invoke "air-related" rules first, simultaneously alerts the appropriate forward air defense units and the headquarters operations team.

With the preceding representation of the probable pre-deployment-phase TRIAX support to the J2 and J3 as background, the following portion of the scenario is depicted. Before a ground force confrontation occurrs, quickly reviewed are (1) the precipitous events in the Soviet Union and Iran, and (2) the timely positioning of the CENTCOMM forces because of their already-described in-garrison preparations.

Scenario

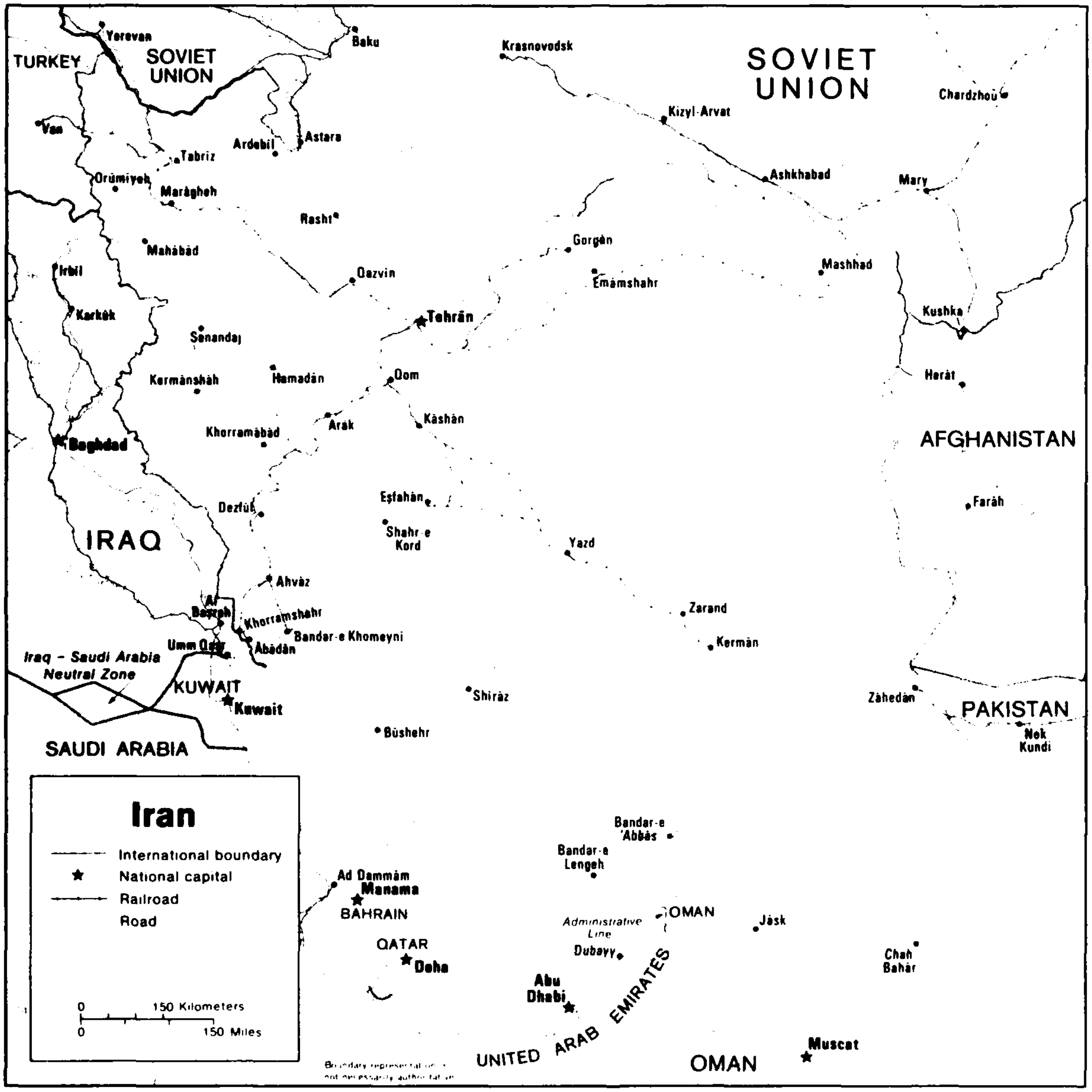
The economic quality of life had so deteriorated in the Soviet Union that civil disobedience, despite the heavy-handed recriminations of the KGB, fomented much anxiety within the politboro. At the same time, the slow but steady growth of the communist Tudeh Party within Iran had permitted the opportunistic Soviets to greatly expand their influence in the newly established coalition government in Tehran. In sum, to divert the Russian populace from their preoccupation with socio-economic misfortunes and to take advantage of an unstable political situation in Tehran, the Soviets moved into northwestern Iran,

ostensibly at the request of the Iranian government. This action consequently compelled the coalition to quickly split into a Tudeh minority in Tehran and a more moderate, pro-west faction in Shiraz.

Because the indications and warnings of Soviet intentions were available at least thirty days beforehand, and the U.S. had exhausted all avenues of diplomacy, the U.S. Central Command was pre-positioned in the region as a final signal of deterrence. Thus, when a Soviet Army Front deployed into northwest Iran from their Transcaucusus Military District twenty five days after the arrival of the U.S. forces, the Central Command (CENTCOMM) forces, at the request of the Shiraz-based government, were able to swiftly react and assume positions north of a line from Dezful to Esfahan as shown in Figure 3.

During the ensuing days, the Soviet and U.S. actions consisted primarily of air strikes against lines of communications. Initial interest of Soviet air activity appeared to be directed in the vicinity of Hamadan, a key crossroad in the western portion of Iran. Of singular importance was control of a nearby bridge linking vital road and land lines between the north and south. U.S. forces protecting this bridge in the area consisted of a battalion of airborne infantry.

At present, operations are running relatively smoothly at the CENTCOMM Joint Task Force Headquarters. As the hostilities are about to intensify, and opposing ground forces begin closing, the national as well as organic CENTCOMM intelligence assets have been reflecting significant Soviet activity within northwestern


Iran
International boundary
National capital
Railroad
Road
0 150 Kilometers
0 150 Miles
TURKEY
SOVIET UNION
SOVIET UNION
Yerevan
Baku
Krasnovodsk
Kizyl-Arvat
Chardzhou
Ashkhabad
Mary
Van
Tabriz
Ardebil
Astara
Orūmiyeh
Marāgheh
Rasht
Mahābād
Gorgān
Emāmshahr
Mashhad
Irbil
Qazvin
Tehrān
Kushka
Karkūk
Sanandaj
Kermānshāh
Hamadān
Qom
Herāt
Kāshān
Arāk
Khorramābād
Baghdad
AFGHANISTAN
Esfahān
Dezfūl
Shahr-e Kord
Farāh
IRAQ
Yazd
Ahvāz
Al Basrah
Khorramshahr
Zarand
Bandar-e Khomeyni
Abādān
Kermān
Umm Qasr
Iraq - Saudi Arabia Neutral Zone
KUWAIT
Kuwait
Shīrāz
Zāhedān
PAKISTAN
Nok Kundi
SAUDI ARABIA
Būshehr
Bandar-e 'Abbās
Bandar-e Lengeh
Ad Dammām
Manama
BAHRAIN
Administrative Line
OMAN
Jāsk
QATAR
Doha
Dubayy
Chah Bahār
Abu Dhabi
UNITED ARAB EMIRATES
OMAN
Muscat

Iran as well as back in the Transcaucusus. In service of all the CENTCOMM forces, TRIAX is interoperatably linked to small, man-transportable mini-TRIAX systems deployed with the foward Corps and Divisions. The TRIAX system is then the automated hub of the sense-decide-execute cycle (page 9) joining national, theater, and organic C3I assets together.

Of particular interest to the analysts of the J2 is the air activity around both Kirovabad and the now Soviet-occupied Tabriz air field. As the constant stream of SIGINT and PHOTINT reports reflect the transit and buildup of HIP and HOOK helicopters as well as MIG-23 FLOGGER aircraft at Tabriz, the analysts can, in near real time, derive current Soviet orders-of-battle status. TRIAX, as it has been updating the incoming message data base and the air orders-of-battle, has been simultaneously applying pre-deployment-entered artificial intelligence (AI) rules to these data bases. Suddenly, the analysts are alerted by TRIAX as sensors report the deployment from Tabriz of many helicopters and fighters to the south. Where are the fighters headed? Are they flying an offensive mission or perhaps just moving forward to another base? Are the HIPs and HOOKs full of assault troops? Are the helicopters also just moving forward to a base closer to the front line?

As could be expected, all of these contingencies were not among those that were carefully thought through and entered into the knowledge data base while in the U.S. Hurried consultations among the J2 and J3 staffs yield modifications to old rules and the addition of new productions to TRIAX to better mirror the actual hostile environment. The J3 staff then employs TRIAX in a

"war-gaming" mode to essentially plan, project, and evaluate different courses of action. After all, a relatively accurate representation of the Command's areas of operation and interest exist in TRIAX. The system can also graphically display (1) the U.S. forces' positions and strengths and (2) known enemy orders-of-battle. Thus, the staff dynamically models the movement of both forces, and TRIAX, based on its knowledge of Soviet doctrine, orders-of-battle, and environment, returns the combat and logistical consequences. The results of assessments of alternative tactical responses are then available as options to include in their Staff Estimates.

With an updated set of rules, a query of TRIAX's topography file informs the analysts that Sanandaj and Qazvin are suitable for helicopter landings, but the terrain between Tabriz and Hamadan will not accommodate a landing of FLOGGERS. Not only is a landing area not available for FLOGGERS, but TRIAX's meteorlogical data base reports wind gusts of seventy miles per hour.

As time elapses and multi-source intelligence reports the arrival of the helicopters with troops on board at Sanandaj, staff estimates are updated to note that these troops will probably not participate in an assault on Tehran. However, since Hamadan and the key bridge site are well within the reach of the FLOGGERS based in Tabriz, the HIPS and HOOKs are probably refueling for an imminent attack on the bridge south of Hamadan. Based on options presented in the staff estimates, the Commander decides, among other actions, to reinforce U.S. positions around

that bridge.

In summary, the scenario has suggested that the volume-generated problems that severly impact on timely decisionmaking can be minimized by supplementing existing deployable automated services, (i.e., transaction, one message at a time, processing; data base management; graphics; and communications switching) with "expertise." However, there are still problems that underlie/constrain the smooth and swift accomplishment of the mission of an AI-driven system. These difficulties will be recognized in the following chapters.

CHAPTER VI

FOOTNOTES

1. Dr. Frank Verderame, "Overview of Army AI/Robotics," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.53.

CHAPTER VII

THE FUTURE OF ARTIFICIAL INTELLIGENCE

Two major initiatives are now beginning that will significantly influence the development and delivery of effective artificial intelligence-based computer systems. They are **Fifth Generation computer** systems and the **Evolutionary Acquisition** process. This chapter surveys the present status and future trends of artificial intelligence within the context of these two influences.

In the evolution of computer systems, the current stage is described as the **Fourth Generation.** Among its major recognizable characteristics are high-level programming languages, sophisticated database management systems, networks providing connectivity between different computers, color graphics, and integrated word and data processing. Fourth generation computers allow trained users, in addition to programmers, to modify applications. The high cost of fielding computers of this era is primarily due to software development and to salaries.[1]

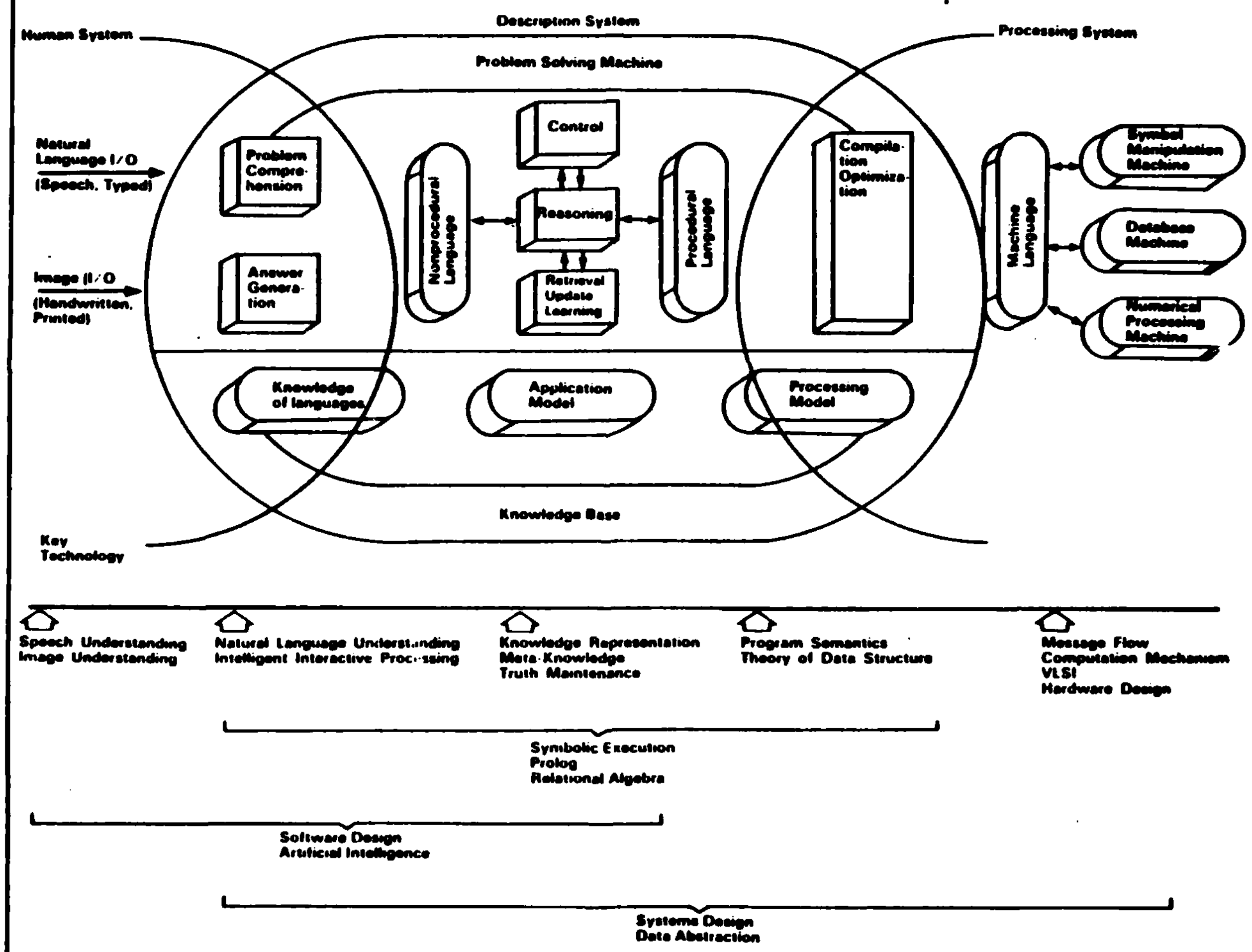
Fifth Generation Computer

Fifth Generation computers will represent a significant advance. The hardware will capitalize on new types of integrated circuits, (i.e., minimal heat-producing Josephson junctions) which will foster faster and smaller computers. A quick perusal of the System Design Concept[2] (Figure 4) reveals that the substance of Chapters III-V of this study are integral components of fifth generation computers. In essence, artificial

DATAMATION 8/81

NEWS IN PERSPECTIVE

SYSTEM DESIGN CONCEPT:
FIFTH GENERATION COMPUTER



FIFTH GENERATION: A very functional system, incorporating artificial intelligence components, is evident in this provocative system design idea for the fifth generation computer.

FIGURE 4

intelligence is the software foundation of the next generation of automated systems. The characteristics of fifth generation computers encompass those fourth generation capabilities plus natural languages for programming, fully integrated heterogeneous computer networks, interactive voice, and transparent applications (i.e., the user does not need to understand the system's programs). Because of this transparency, the system will readily accommodate users with little or no computer training. Thus, the costs of the system, due to the relatively inexpensive software and hardware, are only the salaries of the users and the maintenance people.[3]

A consortium of Japanese technology industries is pioneering the fifth generation computer effort and hopes to produce a prototype by 1990. U.S. experts believe a prototype will take longer to develop because the required artificial intelligence components of the system are not very well understood by the Japanese at this time. Twenty years may be a more realistic estimate.[4]

Partly in response to this Japanese challenge, ten major American computer companies, but not including IBM, are pooling resources, computer experts, and $50 million to develop an American fifth generation computer. Admiral (Ret.) Bobby Inman will lead the new firm -- Microelectronics and Computer Technology Corporation -- in the research and development of advanced computer architecture, software technology, integrated-circuit packaging, and computer-aided design and manufacturing systems.[5]

Evolutionary Acquisition

More often than not during the past decade, the implementation of new technologically advanced panaceas produced substantially more expletives than kudos. The finished products have not equalled the mission requirements. Based on the painful lessons learned, an evolutionary acquisition process is emerging. The traditional acquisition approach rests on a definitive statement of requirements coupled with a "freeze" of design specifications. Then the test and evaluation phase is based on system performance, not mission performance. Also typical of the process is the arms-length relationship between the user and the developer, thereby precluding meaningful interaction.[6]

In contrast, Evolutionary Acquisition (EA) is the process by which, after a mission requirement is articulated and an initial "core" capability (a working model) is fielded, the system can flexibly accommodate change. Evolutionary acquisition also permits iterative interaction between the user and the developers. In addition, functions and subsystems are modularized to facilitate the replacement of obsolescent hardware and software with new technology. The "core" is the initial prototype that models both architecture and partial system capabilties. Subsequent modules add as well as modernize functions.[7]

While most of the deployable software services and hardware components of the scenario's TRIAX exist or will shortly, the AI aspect of TRIAX does not. But yet, the purported TRIAX artificial intelligence propositions were not so far-fetched that

their role in the scenario was inconceivable. Accordingly, with the TRIAX-without-the-AI as the working prototype (or "core" model"), an overview of what is currently available that portends a full AI-capability TRIAX follows.

Current Status of Expert System Development

There is currently no operationally viable expert system in any of the services' inventories. However, many knowledge-based systems are either on the drawing boards or in the early stages of testing by universities and private research and engineering corporations such as MITRE, Stanford Research Institute, and TRW. The sampling below describes current areas of expert systems research.

Intelligence Fusion

A Navy mission required determination of the presence of ocean craft, their classification by type, and an estimation of position, course, and speed. While the data were to be derived principally by manual extraction from sonar displays, the system also had to accommodate nonacoustic data of various sources.[8]

The outgrowth of this requirement, the Surveillance Integration Automation Project (SIAP) explores the feasibility of applying artificial intelligence techniques to the integration of surveillance information for detecting, classifying, and tracking platforms in the ocean. A knowledge-based system has been developed to process multiple types of input using several varieties of knowledge and analysis tools. The system attempts to build and update over time a model of the changing scene being

observed. SIAP uses information derived from signal processing algorithms, statistical analysis, factual knowledge, informal knowledge (heuristics in the form of productions) and knowledge inferred from SIAP's previous conclusions.[9] Through 1980, SIAP's accomplishments demonstrated the real-time classification of ocean traffic, automated processing for multiple-array surveillance, and effective use of nonacoustic input.[10]

TRW is very active in many of the artificial intelligence disciplines. They are advancing programming languages (INTERLISP, ROSIE, Ada, and its subset PASCAL) as well as a dialogue language for designing analyst-system interaction. Their interests focus on the use of AI to improve the performance of large, conventional, real-time applications. As examples, during the past few years TRW has initiated development on Tactical Situation Analysis Rules (TSAR), to aid in the prediction of enemy axes of attack. Through the use of time and event-dependent rule sets, coupled with enemy doctrines and analyst hueristics, TSAR can determine the most probable troop manuevers. The TRW IDENTIFY project can supplement incomplete intelligence and help determine an enemy unit. IDENTIFY also can generate sensor tasking recommendations to eliminate identification ambiguities.[11] Efforts in the TRW Defense Systems Group also have addressed a space defense problem. Their knowledge-based system is designed to aid the analyst with an interpretation of a situation and provide possible courses of action. The computer complex supporting this research includes Xerox and DEC VAX processors and a Chromatics display processor. The services that this prototype provides are very much in

concert with those of TRIAX.[12]

The Air Force is investigating the use of AI for potential application in the situation assessment and tactical decisionmaking areas. These include (1) fusion of airborne and ground base sensors for air situation assessment and (2) Intelligence analyst support systems.[13]

Planning

The MITRE Corporation is also extensively involved in the advancement of AI techniques. One of their efforts is an interactive planning aid called KNOBS. KNOBS is being developed in support of tactical air mission planning and is being transferred to naval mission planning. It offers support during the completion of plans and in the modification of plans by new information. The user is assisted by a program that explains the inconsistencies that have arisen, and decides those considerations that should be rechecked, and those that should be ignored if the plan is changed (either because they are unaffected or are less important than other problems that may have surfaced). The system also provides the user with dynamically generated and preferentially ordered choices consistent with other plan elements. The program responds to questions about the database, posed in English, and further offers the use of restricted English for the explanation and alteration of its own behavior through the modification of its internal logic.[14]

This system takes advantage of the earlier described "frames" and extends their utility to a new class of data

structure called "templates". A template is attached to a generic frame which represents a mission being planned. The template mirrors the contents of the mission's individual frame (e.g., target, aircraft), except that in place of values, one finds rules to supply those values.

MITRE plans to extend KNOBS to integrate entire strike packages including interdiction, refueling, defense suppression, and electronic countermeasures. The next objective is to expand the system's tactical air planning knowledge to the point where a mission planner can, at times, entrust more of the planning initiative to the system. A distant goal is to develop programs that will be capable of automatically learning, i.e., changing their own rules in response to extensive dialogue with mission planners.[15]

War Gaming

Several companies including General Research Corporation, Jet Propulsion Labs, and BDM Corporation are currently modeling land combat. BDM in undertaking two approaches to model command and control, recognizes that command center units must operate together in a hierarchical manner. The models represent a complex environment that allows freedom of the C3I center to operate without being artificially constrained.

The first model is a command and control module for the theater. It simulates a knowledge-based approach in which each command post system entity retains a complex understanding of the situation. Each battlefield situation may be represented as one of a set of general circumstances. A concept of operation may

then be chosen from among those suitable to the general circumstance. Final planning is then carried out by detailing the general concept of operation to the particular situation.

The second, simpler automated model of C3I is useo for lower level units, thousands of which may be present in a particular simulation. This technique allows quicker operation. The representation, based on more abstract binary situation features, requires minimal computer storage space. Other decision processes involved with selection of movement route or artillery munition depend on the unit operational plan chosen.

Execution of operations allows movement in two dimensions, so that operations such as envelopments can be accurately represented. Additionally, communications, sensor models, and other processes all can drive the command and control model.[16]

Hardware

The recent revolution in computer hardware is daily experienced, if not appreciated. The influence of the microprocessor is practically everywhere. Two consequential developments of benefit to the military are occurring. First, the micros are becoming more powerful although their packaging remains compact. The eight-bit machine has given way to the sixteen-bit computer. Simultaneously, because of the miniaturization of components, the high powered, general-purpose, main frames are becoming smaller. This is resulting in small configurations with great processing power. Similiar progress is occurring with the micro's display unit. The GRiD COMPASS microcomputer system, for example, possesses a flat-panel display

screen accommodating both alphanumeric and graphic output. Thus, instead of having to transport separate CRT units, the GRiD COMPASS screen folds into the micro package.[17]

The second development is the TEMPESTing (or electro-emanation suppression) of personal-size computers such as the Apple and IBM models. This will facilitate an expeditious fielding of the most recent software advances in computer systems.

The preceding survey of current research shows the progress of expert systems toward supporting a command center. Moreover, there is concomitant progress in the fields of robotics for tanks, helicopters, and artillery, vision (imagery), weapon system controls, and logistics. Underlying the advancements in most of these disciplines is the existence of the necessary hardware, software, and language tools to enable this development. In review then, nationwide research is pursuing the principles of the evolutionary acquisition process (develop a function and test it) which will likely lead to AI systems responsive to the increasing demands of the C3I environment.

Accordingly, through the near (to-1985), intermediate (to-1990), and 1995 time frames, continued incremental advancements toward the objective fifth generation computer can be expected. Moreover, hardware and communications costs will continue to decline. During the last six years, computer memory, computer logic, and communications costs have decreased 40, 25, and 11 percent, respectively each year.[18] Because a TRIAX is a specific application of a fifth generation computer, and since

many companies are working on expert system functions and modules, the availability of an effective AI service for command post Intelligence Centers will likely precede the fifth generation computer itself.

AI Trends For The Long Term

The last five years of the twentieth century will likely result in a proliferation of today's initiatives in artificial intelligence and expert system development tools. In fact, 1995 through 2010 may become the period of transition from conventional computers to automated systems driven by artificial intelligence.

One of the expensive tasks of the late 1990's will be that of converting programs to Ada software. Naturally, one must be wary of disrupting an operational system by converting its program code, but as its hardware becomes obsolete or as system requirements demand the same functional services, but with extended capacity, the replacement system will have to be recast with Ada.

There will no doubt be other breakthroughs that will yield increased capacities in hardware and communications capabilities. As an example, the successful operation of a prototype fifth generation computer will necessarily spawn a network of artificial intelligence-based systems. Distributive AI will be differ from the current concept of distributive processing in that one AI computer will be able to "know" the goals of another AI system and subsequently delegate tasking and responsibility throughout the net.[19]

The 1990s will place the onus for system viability squarely on the commander, staff, and analysts. Although near- and intermediate-term progress will result in incrementally "smarter" expert systems to support the command post, future advancements in the Operations Center, specifically, may be slowed if sufficient decisionmaker time is not devoted to the system. The problem, to parphrase a production adage is, "If a commander has the spare time, then that person is about to retire."

The objective of AI is to emulate an individual's cognitive process, and degree of accomplishment in the military environment is directly related to the commander's commitment to understand his system and provide his knowledge and heuristic insights. The cost, of course, is a significant dedication of his time to the formulation and enhancement of the system's decisionmaking component. Let there be no misunderstanding of the difficulty in exacting and applying the cognitive process. For instance, even the simplest daily routines that are carried out reflect decisions based on years of reinforced experiences and intuition. The dynamic, high-stress environment of combat will hardly require less preparation. The examples of productions used in the Iran scenario and throughout the study are very rudimentary, but illustrate the complex nature of applying AI to C3I.

The operational ramifications of having a TRIAX at the hub of C3I activities is that the commander, his staff and analysts must function as a team as rarely before if the system is to perform at its maximum potential. Therein lies the future and success of artificial intelligence systems.

CHAPTER VII

FOOTNOTES

1. David S. Alberts, "Information Systems for Command and Control,(U)" ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION Course Proceedings of Command, Control, Communications and Intelligence Symposium (SECRET), Vol. 1, pp. 253-4.

2. Dr. Frederick Hayes-Roth, "Artificial Intelligence and Expert Systems," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.141.

3. David S. Alberts, pp. 253-4.

4. "A Fifth Generation: Computers That Think," Business Week, Number 2718, 12 December 1981, pp.94-96.

5. "Counterattack," TIME, 7 February 1983, p. 50.

6. David S. Alberts, "Evolutionary Acquisition and Evaluation of C2 Systems (U)," ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION Course Proceedings of Command, Control, Communications and Intelligence Symposium (SECRET), Vol. 4, p.441.

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8. Dr. John Anton, "Artificial Intelligence for Ocean Surveillance," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.377.

9. Robert J. Drazovich, Scottie Brooks, and Scott Foster, "Knowledge Based Ship Classification", First U.S. Army Conference on Knowledge-Based Systems for C3I, p. 163.

10. Dr. John Anton, pp.389-390.

11. Dan Newell and Jim Novak, "Knowledge Engineering In Support Of Intelligence Fusion," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.175.

12. David A. Brown and Harvey S. Goodman, "Artificial Intelligence Applied to C3I," ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION PROFESSIONAL PAPERS SESSIONS, pp. 10-12.

13. Robert J. Drazovich and J. Roland Payne, "Artificial Intelligence Approaches To Information Fusion," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.160.

14. C. Engleman and E. A. Scarl, "KNOBS: An Interactive Planning Aid," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.263.

15. Ibid., p.271.

16. John B. Gilmer, "Knowledge-Based Implementations Of C2 In Land Combat Models," First U.S. Army Conference on Knowledge-Based Systems for C3I, p.263.

17. BDM Management Services Company, Improvement Opportunities For Automation And Communications (Draft Report), pp. 10-11.

18. David S. Alberts, "Information Systems For Command and Control (U)," ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION Course Proceedings of Command, Control, Communications and Intelligence Symposium (SECRET), Vol. 1, p.257.

19. Nils J. Nilsson, "Distributive Artificial Intelligence," Defense Technical Information Center Technical Report.

CHAPTER IIX

RECOMMENDATIONS AND CONCLUSION

Recommendations

The small difference in years between 1983 and 2000 plus the knowledge of how fast time passes results in the imminent arrival of the Twenty-first Century. For those actions that can be initiated now to facilitate an orderly and timely transition to the fifth generation computers technology of the year 2000 and beyond, the following recommendations can serve as a starter set.

Mission

The primary responsibilities of the Intelligence and Operations Centers of the garrisons and deployed commands will remain essentially as they are. This will provide functional stability and continuity over the years for the development of new expert systems such as TRIAX. In other words, as the C3I center users discuss the operational and human engineering specifications for a future TRIAX with system designers, there need be no ambiguities due to changing center functions. Today several automated services that support in-garrison Indications and Warnings and the Operations Centers but would not be deployed with the forces because of the equipments size, lack of ruggedness and TEMPESTing, and its dependence on civilian maintenance. The overriding objective is to have the system that is used in-garrison as the system taken to war. If the system that is deployed with the forces is not a clone of the in-garrison system, it should be only a scaled-down functional

version of the larger computer facility. Then updated databases can be tranferred to the TRIAX as it accompanies the deploying headquarters.

The operational network of future TRIAXs should extend to at least the battalion command and control centers. The systems at the lower echelons would possess TRIAX systems scaled-down to their needs. Advanced organic communications carriers and software-based packet-switching and automatic network reconfiguration will provide redundant connectivity among the units. The portability of a "mini-TRIAX" will allow this.

With the increasing employment of communications-interfaced computer systems in the deployed centers, problems will surface during data transmission that may originate in the computer. Generally speaking, because the Technical Controllers of the CENTCOMM Forces Communications elements, are inexperienced in computer architecture, they can only check their circuits to determine whether or not the problem is their own. The C3I center analyst is most familiar with his operational mission but is not well-versed on computer diagnostics or communications facilities. Thus, a specialist is needed to expeditiously isolate and resolve the communications/computer crossover perturbations. vital. Accordingly, the symbiotic relationship between computers and communications can be maintained by providing the C3I center with personnel skilled in both areas and, in the future, in artificial intelligence. The requirement for assignment to some C3I staff positions is at least a secondary Military Occupational Specialty in Telecommunications and Computers. The objective is to have staff members who are knowledgeable about the operational

mission as well as teleprocessing.

System Acquisition

As indicated earlier in this study expert system support to the command centers will ultimately require a tailored version of a fifth generation computer. Thus between now and 1990-95, command centers will need to remain abreast of the advances in AI processing. Periodic briefings and visits to universities and research and development companies would help ensure that systems acquired for the near and intermediate terms will be compatible with the transition to AI systems. Guidance provided to interested companies not currently engaged in artificial intelligence research should include:

-- The development of a core model of their proposed system to permit evolutionary acquisition.

-- The capability to program the system in Ada.

-- The development of AI systems that would be compatible with productions and use of natural languages.

Training

The staff and analysts operating the TRIAX will require training not only to manipulate the system as they currently do (i.e., for database retrievals and management, message preparation, and calculations), but also to understand the control strategy and productions of expert systems. Fortunately, the next generation of command-post C3I personnel will have grown up with computers. Their familiarity with

automation augurs well for maximizing the performance of their system. TRIAX training, as with all other forms of learning, requires frequent reinforcement. This underscores the need to have the deployable system or its clone as an intergral component of daily in-garrison operations. By this means, morevoer, the decisionmaker would have direct access to his dynamic system -- the critical factor in its viability.

Another rationale for the in-garrison use of the combat support TRIAX is to stress it applicability the system as a real-world system. If a TRIAX were only employed during quarterly exercises, the training would be mostly forgotten, and the subtle heuristic lessons-learned would have to be rediscovered the next time out. Full-time employment of the system obviously remedies these situations.

Some of the above recommendations may not be original nor startling revelations, but the author has not experienced these common-sense practices in wide-spread application.

Conclusion

These eight chapters have summarized the symbiotic artificial intelligence disciplines, the components of expert systems, their current status, and future potential.

Artificial Intelligence is currently the only viable and cost-effective approach to solving many problems where volume, limited skilled human resources, and timeliness are critical constraints.

Even though human thinking is a difficult and complex process, the new methods of simulating cognitive activities,

continual breakthroughs in software and hardware technology, and a more realistic acquistion process will ultimately provide the necessary tools to effectively employ C3I resources.

In the course of surveying the industries developing artificial intelligence, it has become evident that the defense services and agencies have a ground-floor opportunity, through evolutionary acquisition, to become involved in the design of systems that will eventually support their combat mission.

Because research and development are both expanding and accelerating, this study, having cited the disciplines being pursued and having listed some of the involved institutions, can serve as an index to further detailed investigation.

When the TRIAXs of the future arrive on station, they will contribute immeasurably in converting volumes of C3I into a manageable intelligence asset. However, it will be the contribution of dedicated and skilled personnel, the human dimension, that will transform the TRIAX into a viable decisionmaking aid and a true force multiplier. The leadership challenge for the 1980s is to prepare for the AI system of the 1990s.

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